

Flexible Electrostatic Technologies for Capture and Handling, Phase 1

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Sponsoring Program(s)

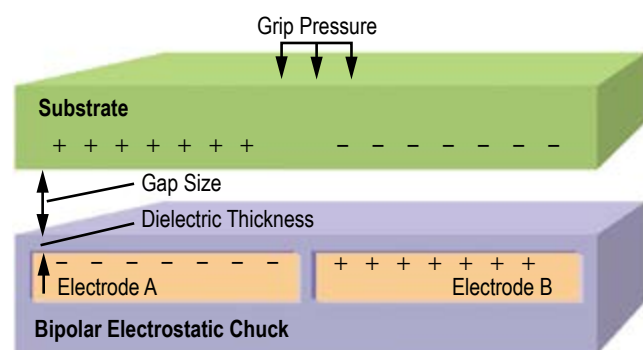
Space Technology Mission Directorate
Center Innovation Fund

Project Description

Fundamental to many of NASA's in-space transportation missions is the capture and handling of various objects and vehicles in various orbits for servicing, debris disposal, sample retrieval, and assembly without the benefit of sufficient grapple fixtures and docking ports. To perform similar material handling tasks on Earth, pincher grippers, suction grippers, or magnetic chucks are used, but are unable to reliably grip aluminum and composite spacecraft, insulation, radiators, solar arrays, or extra-terrestrial objects in the vacuum of outer space without dedicated handles in the right places.

The electronic Flexible Electrostatic Technologies for space Capture and Handling (FETCH) will enable reliable and compliant gripping (soft dock) of practically any object in various orbits or surfaces without dedicated mechanical features, very low impact capture, and built-in proximity sensing without any conventional actuators. Originally developed to handle semiconductor and glass wafers during vacuum chamber processing without contamination, the normal rigid wafer handling chucks are replaced with thin metal foil segments laminated in flexible insulation driven by commercial off-the-shelf solid state, high-voltage power supplies. Preliminary testing in NASA Marshall Space Flight Center's (MSFC's) Flat Floor Robotics Lab demonstrated compliant alignment and gripping with a full-sized, 150-lb microsat mockup and translation before a clean release with a flip of a switch. The flexible electrostatic gripper pads can be adapted to various space applications with different sizes, shapes,

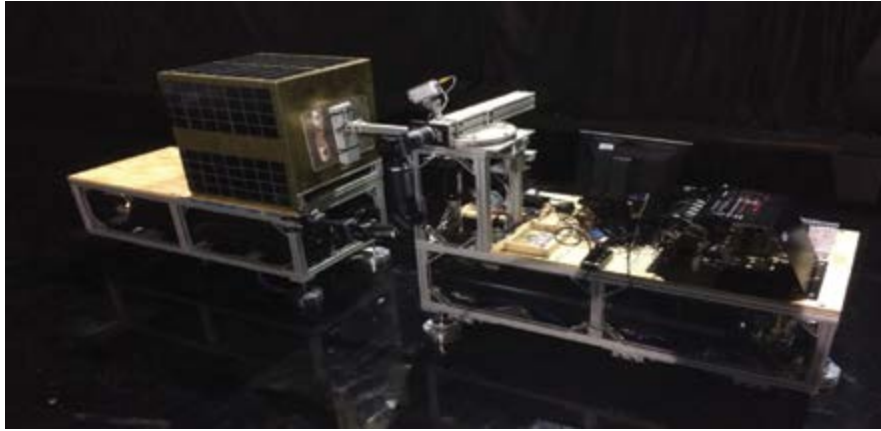
and foil electrode layouts even with openings through the gripper pads for addition of guidance sensors or injection of permanent adhesives. With gripping forces estimated between 0.5 and 2.5 lb/in² or 70–300 lb/ft² of surface contact, the FETCH can turn on and off rapidly and repeatedly to enable sample handling, soft docking, in-space assembly, precision relocation, and surface translation for accurate anchoring.



Electrostatic grip illustration.



Actual electrostatic gripper (unmounted).



FASTSAT mockup capture and handling from air-bearing mini space tug simulator.

Anticipated Benefits

The need to capture, handle, and assemble very large objects and modules is a key technology gap that will enable or prevent MSFC and this Agency to piece together the giant ships that will be used to sail beyond Earth orbit and the Moon. The ability to reach out and grip and handle objects enabled the evolution of primates to travel across the oceans and now across space to other worlds and any technology that will enable us to grip and handle with greater capability in various environments will enhance NASA's capability for space exploration. NASA has investigated the flexible electrostatic (ES) grippers for 2 years in MSFC's Flat Floor Robotics Lab with various development activities including purchase, testing, modification, and demonstration of the ES grippers with various spacecraft materials and configurations, with future ongoing testing.

Potential Applications

This new capability to sense proximity, flexibly align to, and attract and cleanly grip and capture/translate practically any object or shape in space without any predesigned physical features or added sensors or actuators will enable or enhance many of MSFC's strategic emphasis areas in space transportation and space systems: (1) Flexible ES grippers on booms will enable assembly of thermal shields, radiators, or arrays from modules to form the vehicle stacks for advanced in-space propulsion technology test-bed demonstrations and transportation missions (using Cryogenics, nuclear, sails, tethers, etc.) for beyond Earth orbit (BEO) exploration such as Mars missions; (2) Flex ES grippers on booms will enable commercial cargo vehicles to berth to the International Space Station (ISS) from a safe

station-keeping distance with minimum crew support and without the ISS robot arm; (3) Flexible ES grippers will enable noncontaminating inspection robots to crawl outside and inside modules, engines, and the ISS using only power with no rails, handles, and without the fuel, complexity, and safety issues of free-flying robots to support advanced in-space propulsion test-beds and systems, innovative BEO exploration, habitation module outfitting, and low-cost ISS payloads; (4) An ES gripper-based rover can attach to and transverse any slope, any angle under low or no gravity in vacuum without anchors, crevasses, propulsion, or contamination and will enable 'gravity boots' for extra-vehicular activity walking cradles for exploration; and (5) Flexible ES grippers on booms can capture, de-spin, and handle sample canisters and space vehicles from a safe distance with minimal thruster use for sample return, satellite servicing, and debris relocation.

Notable Accomplishments

We have demonstrated that a flexible electrostatic or electroadhesion gripper that is all electric and can conform and capture various shapes, sizes, and materials without target preparation generates pull-in force across the gap to grip and self-align (similar to magnetics), and releases cleanly without active motors in space. The following video is a demonstration of a thruster propelled approach to a full-scale, fast, affordable science and technology satellite (FASTSAT) mockup on air-bearings (~150 lb) and the electrostatic gripper activating, gripping, and moving the mockup through the gripper with the mini space tug simulator's thrusters: <https://www.youtube.com/watch?v=Zm-naczMdhU>.